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Jon W Dudas

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. EJ283615288US

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
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Additional inventors are being named on the ______ *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

Membrane structures with thermo-regulating properties

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* 5
☒ Drawing(s) *Number of Sheets* 1
☒ Application Date Sheet. See 37 CFR 1.76
☐ CD(s), Number ______
☒ Other (specify) Title sheet-1p

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☒ Applicant claims small entity status. See 37 CFR 1.27.
☒ A check or money order is enclosed to cover the filing fees.
☐ The Director is herby authorized to charge filing fees or credit any overpayment to Deposit Account Number: ______
☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE Amount ($): 80.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.
☐ Yes, the name of the U.S. Government agency and the Government contract number are: ______

Respectfully submitted,

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Date 07/21/2003

REGISTRATION NO. ______ *(if appropriate)*

Docket Number: ______

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

PROVISIONAL APPLICATION FOR LETTERS PATENT

Inventor: Barbara H. Pause

MEMBRANE STRUCTURES
WITH THERMO-REGULATING PROPERTIES

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as "Express Mail" in an envelope addressed to Assistant Commissioner for Patents.

Date: July 21, 2003 Barbara H. Pause

Barbara H. Pause

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Membrane structures with thermo-regulating properties

Abstract

The energy efficiency of buildings with membrane roof constructions is generally low due to the lack in sufficient thermal insulation capabilities. The problem can be solved by using phase change material (PCM). PCM is a highly productive thermal storage medium, which can be used in a membrane structure to absorb heat during the day and release the stored heat overnight. This thermo-regulating effect lead to an improved thermal management of such building structures. The PCM is incorporated in a silicone rubber matrix and then coated on a polyester fabric or a fiber glass fabric which are commonly used for membrane structures. The membrane structures with PCM possess high latent heat storage capacities. They satisfy the necessary mechanical and fire resistant requirements. The light transmission through the membrane structures is high, but varies with the membranes temperature.

Introduction

Membrane materials used for roof structures of buildings provide a relatively low thermal insulation capacity compared to the classic building materials. Therefore, a large amount of heat penetrates daily through such roof structures into the building especially during the summer months leading to an overheating of the buildings interior. On the other side, the nightly heat loss through such roof constructions, specifically during the winter months, is significantly high.

The problem can be solved by using newly-developed membrane materials with thermo-regulating properties. The thermo-regulation properties of these membrane materials are obtained by the application of phase change material (PCM) - a highly productive thermal storage medium.

Phase change material (PCM)

Phase Change Material (PCM) possesses the ability to change its physical state within a certain temperature range. When the melting temperature is obtained in a heating process, the phase change from the solid to the liquid state occurs. During this melting process the PCM absorbs and stores a large amount of latent heat. The temperature of the PCM and its surroundings remains nearly constant during the entire process. During the cooling process of the PCM, the stored heat is released into the environment in a certain temperature range, and a reverse phase change from the liquid to the solid state takes place. During this crystallization process, the temperature of the PCM and its surroundings remains also constant.

In order to compare the amount of latent heat absorbed by a PCM during the actual phase change with the amount of sensible heat in an ordinary heating process, the ice-water phase change process will be used for comparison. When ice melts, it absorbs an amount of latent heat of about 335 J/g. When the water is further heated, it absorbs a sensible heat of only 4J/g while its temperature rises by one degree Celsius. Therefore, the latent heat absorption during the phase change from ice into water is nearly 100 times higher than the sensible heat absorption during the heating process of water outside the phase change temperature range.

In addition to ice (water), more than 500 natural and synthetic PCMs, such as paraffins, salt hydrates, metallics or salt eutectics are known. These materials differ from one another in their phase change temperature ranges and their latent heat storage capacities.

Thermal benefits

A major benefit of the PCM application in membrane materials is the improvement in their thermal performance which has a significant influence on the thermal management of the entire building. In its roof application, the PCM starts to absorb the heat provided by the solar radiation during the day as soon as the membrane material's temperature exceeds a given value. During the heat absorption by the PCM, its temperature and the temperature of the surrounding membrane material remains nearly constant. Therefore, the heat absorption by the PCM reduces the heat flux into the building during the day. Especially on hot summer days, the thermal comfort inside the building will be enhanced significantly as a result of the PCM's heat absorption feature. The PCM releases the stored heat overnight in a reverse cooling process, which also reduces the heat flux through the membrane structure and, therefore, results in a significant reduction of the nightly heat loss through the roof. Applying PCM to the building's envelope, the overall heating and air-conditioning demands of the facility will decrease and the construction becomes more energy efficient.

Based on the improved thermal performance of the membrane structure by the PCM application, changes from multi-layer membrane roof construction to single layer membrane roof constructions could be taken into consideration in some circumstances. This would result in substantial material savings.

Another benefit arising from the PCM application in membrane structures is the expectation of a significant delay in the materials aging process. The material aging is usually accelerated by high material temperatures and significant temperature fluctuations. Reducing the temperature increase in the afternoon and minimizing the daily temperature fluctuations, therefore, will enhance the service lifetime of membrane construction substantially.

Product design

In a membrane application, the PCM needs to be properly contained in order to prevent dissolution while in its liquid state. Although PCMs are often difficult to contain, silicone rubber was found to be an appropriate carrier system. Manufacturing the membrane material with thermo-regulating properties, the PCM is first mixed into the components which create the silicone rubber matrix. Liquid silicone rubber ELASTOSIL RT 625 is a proper silicone rubber matrix the PCM can be easily mixed into. In the next step, the system is cured and then topically applied to a suitable basic membrane material such as a polyester fabric or fiber glass fabric by knife coating. In order to receive a proper adhesion silicone primer P-80 needs to be applied to the polyester basic fabric before the coating. The drying process should be carried out at about 50 °C. the drying process takes about one hour. In order to connect two of such membrane materials to each other they may bonded by means of glue.

Temperature measurements in membrane constructions were carried out in order to investigate the temperature range in which the PCM should absorb heat. The appropriate temperature range for the latent heat absorption of the PCM was determined to be about 30 °C to 45 °C.

Considering this temperature range, a PCM was selected which absorbs latent heat in a temperature range between 30 °C and 39 °C and releases heat in a temperature range between 15°C and 20 °C. The chosen PCM is a non-combustible salt hydrate which possess a high latent heat storage capacity of about 230 J/g.

Discussion of test results

The membrane materials summarized in Table 1 have been tested regarding their thermal insulation properties. The test results are summarized in Table 2. The basic thermal resistance characterizes the thermal resistance value of the specific membrane material. The heat absorption of the PCM, which takes place when a certain temperature is obtained in a heating process, leads to a temporary decrease in the heat flux through the membrane material causing an additional insulation effect, called "dynamic thermal resistance". The total thermal resistance of a membrane material equipped with PCM is the sum of the material's basic thermal resistance and the dynamic thermal resistance by heat absorption of the PCM. For membrane materials without PCM the total thermal resistance equals the material's basic thermal resistance.

Table 2: Thermal insulation properties of selected membrane materials

Membrane material	Basic thermal resistance, m^2K/W	Dynamic thermal resistance by heat absorption of the PCM, m^2K/W	Total thermal resistance, m^2K/W
PES/PVC	0.0073	-	0.0073
Fiber glass/silicone	0.0054	-	0.0054
Fiber glass/silicone rubber with PCM	0.0096	0.0230	0.0326

Ordinary membrane materials such as PVC coated polyester fabrics and silicone coated fiber glass fabrics possess only a low thermal resistance due to their low thickness and high density. The comparatively higher thickness and lower density of the fiber glass fabric with the silicone rubber/PCM coating on one side leads to a slightly higher basic thermal resistance of this membrane material. However, the heat absorption by the PCM during the day provides an additional (dynamic) thermal resistance which results in a temporary increase of the material's total thermal resistance of about 140 %.

The daily heat absorption and the nightly heat emission of the PCM limit the heat flux into and out of a building covered with an membrane roof to which PCM is applied. A comparison test was carried out using two model buildings. One of the model buildings was equipped with a roof structure made of a PVC coated polyester fabric. The roof of the second model building consisted of a silicone rubber /PCM coated fiber glass fabric. In both test configurations only a single layer membrane construction was used. Temperature measurements were carried out in a similar distance underneath the two membrane structures. The temperature developments obtained for the two model buildings on the same day are shown in Figure 1.

The test results, shown in Figure 1, indicate that there is a substantial delay in the temperature increase during the day due to the heat absorption by the PCM. The results are temperature differences of up to 9 K between the two buildings. Furthermore, there is also a delay in the temperature decrease overnight due to the heat release of the PCM. However, the test results indicate that the membrane material in its current makeup especially supports the heat absorption process by the PCM. The overall daily temperature fluctuations measured under the specific climatic conditions were reduced by about 8.5 K due to the thermo-regulating process of the PCM.

The newly-developed membrane materials show interesting features regarding light transmission. Their translucencies change in the course of the day. The silicone rubber layer with the PCM becomes transparent as soon as the PCM is completely melted. On the other side, when the PCM crystallizes the silicone rubber layer with the PCM becomes opaque.

The light transmission of a PVC coated polyester fabric, a silicone coated fiber glass fabric, and a silicone rubber with PCM coated fiber glass fabric has been tested. The test results are summarized in Table 3.

Table 3: Light transmission of the selected membrane materials

Membrane material	Translucency, %
PES/PVC	5
Fiberglass/silicone	23
Fiberglass/silicone rubber with PCM	54 (PCM in liquid state) 39 (PCM in solid state)

The test results indicate that the translucency of the newly-developed membrane material exceeds the translucency of the membrane made of a PVC coated polyester fabric and a silicone coated fiber glass fabric significantly. The difference in the light transmission between the two states of the PCM incorporated into the silicone rubber which is coated onto the fiber glass fabric totals 15%. Similar results respective the silicone rubber with PCM coated fiber glass fabric were received for a polyester fabric which was coated with silicone rubber with PCM.

Other features of the newly-developed membranes consisting of fiber glass coated with silicone rubber with PCM are very similar to those of membranes made of silicone coated fiber glass. These features are:

- Temperature resistance between –50 °C and 200 °C,
- Non-combustible (flammability class A2),
- Dirt repellency (self cleaning during rain),
- Durable elasticity,
- High tensile strength,
- High dimensional stability,

- Resistant to a variety of chemicals,
- Resistant to weathering and aging.

The aging feature of the newly-developed membrane material is expected to be even improved compared to ordinary silicone coated fiber glass fabrics as a result of the improved thermal management.

Conclusions

The newly-developed membrane materials with PCM incorporated into a silicone rubber matrix and topically applied to a basic fabric usually used for architectural membranes offer a unique set of improved thermal performance capabilities previously unattainable in an architectural membrane fabric. These capabilities will enable a substantially improvement of the thermal management of buildings with membrane enclosures. The enhanced thermal management reduces the buildings air-conditioning and heating demands, and, therefore, makes the building more energy efficient. In addition, the presently used multi-layer systems could be reduced to only a one-layer systems which leads to substantial material savings. The reduced temperature fluctuations the membrane material is supposed to during the day may influence the materials aging behaviour in a positive manner which will lead to a longer service life. A unique feature of the newly-developed membrane materials is the change in their light transmission properties as a result of temperature changes, which might be especially interesting for architectural applications.

Drawing for the provisional application

Membrane structures with thermo-regulating properties

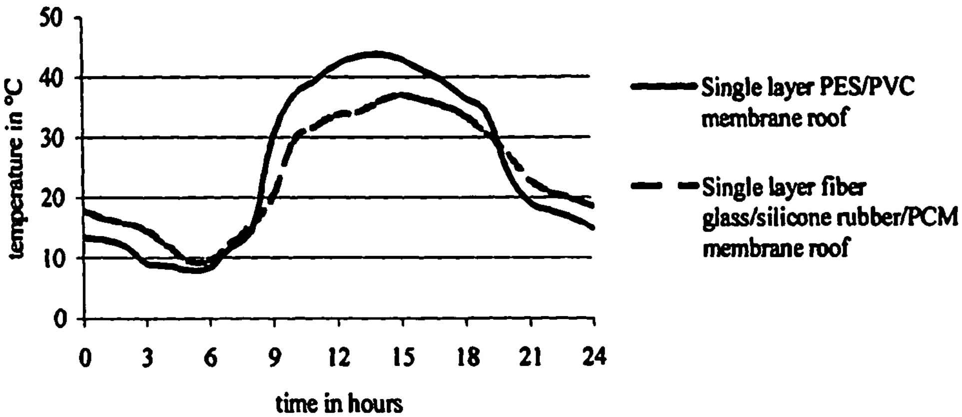

Figure 1: Temperature development inside the model building

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention Membrane structures with thermo-regulating properties

As the below named inventor(s), I/we declare that:

This declaration is directed to:

[X] The attached application, or

[ ] Application No. ____________, filed on ____________,

[ ] as amended on ____________ (if applicable);

I/we believe that I/we am/are the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought;

I/we have reviewed and understand the contents of the above-identified application, including the claims, as amended by any amendment specifically referred to above;

I/we acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me/us to be material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT International filing date of the continuation-in-part application.

All statements made herein of my/own knowledge are true, all statements made herein on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and may jeopardize the validity of the application or any patent issuing thereon.

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Signature: ____________ Citizen of: ____________

[ ] Additional inventors or a legal representative are being named on ____________ additional form(s) attached hereto.

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